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electric boat engines & solar power

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EMUS BMS (battery management system) for LiFePo 4 batteries

SETUP INSTRUCTIONS

Note: The BMS module is manufactured in Europe. The systems are assembled in Australia. This document only applies to the EMUS BMS system setup offered in Australia. One year limited warranty applies to all products supplied via all4solar.

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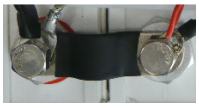
Material required (partly optional)

●Prismatic battery cells
with 8 or 10 mm connectors

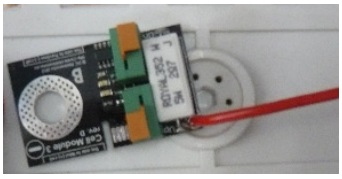
●Lugs for main cable connections (8 - 10 mm)
Cables usually 32 - 70 mm2

●Suitable sized cable

●Cell connectors
With bolts and washers



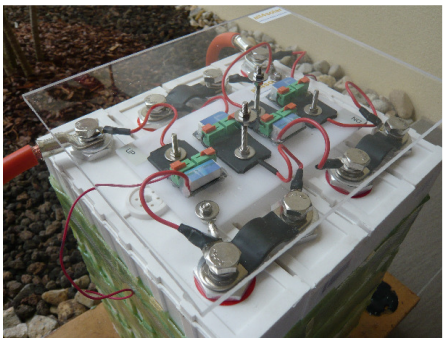
●Antioxydant



●Cell balancers EMUS digital
(Standard with one cable and
8 mm connector)

or

●Cell balancers EMUS digital
all prewired in blocks of 4 on a
acrylic board with cover plate



●Lugs for balancers (8 - 10 mm)
(included with EMUS Balancer)

●Cable to connect balancers (1-2 mm2)
(included with EMUS Balancer)

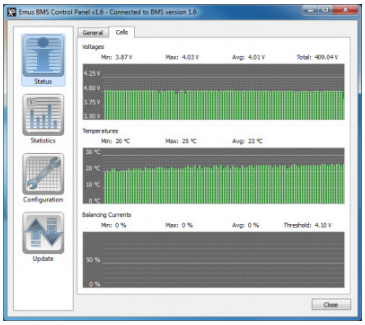
●BMS controller EMUS digital

●Setup plug with cables / USB for BMS
(included with EMUS BMS)

●DC DC converter to 12 V DC for BMS

●Fuse for power to BMS (12 V DC)

●Software to setup and monitor BMS
(included with EMUS BMS)



●Plug & cables for final cable connections
(included with EMUS BMS)

●BOT isolators (negative / positive)
(Included with EMUS BMS)

●CAN Bus Group Module

●Blue Tooth Module

●Main switch for power supply on/off
●Main switch for charger on/off
●Main switch for load on/off

●LED for status with cable

●Android tablet with preinstalled EMUS app

●Main contactor load (100-300 A) switched by relay max. 0.5 A

●Main contactor charge(50-100 A) switched by relay max. 0.5 A (conventional charger)

●CAN Bus charger

You can setup and wire the whole system or we can pre wire the system for you. The pre wiring does not include the main cables if those are not ordered separately. The pre wiring includes the pre wiring of all the balancer units, the cables to the controller and the marking of all cables to be connected to the battery cells, charger etc.

1) Safety Warning

Handling LiFePo4 batteries requires knowledge and safety precautions. Incorrect handling can damage batteries and attached systems and cause serious injury! Read all manuals from the battery cell supplier.

2) Preparation of batteries

LiFePo4 cells usually have a certain nominal voltage (3.2 - 3.4 volts depending on manufacturer) and a certain capacity (in Amps). The supplier gives you the maximum discharge and charge rate - usually in C - figures. C1 = maximum rate in 1 hour.

Example:

100 A cell with C0.5 charge and C2 discharge = 50 A max. charge rate and 200 A max discharge rate.

The single battery cells have to be assembled in cell blocks by fixing them with solid steel bands or frames to avoid any movement and expansion. A basic rule is, that 4 prismatic cells are mounted in one block for 200 Amp cells and 8 prismatic cells are mounted in one block for 100 Amp cells. The blocks can be connected with flexible cables or with cell connectors, if the blocks are fixed. The cell connectors may not receive any tension from moving cells!

There are different options how to assemble the cells

Steel - Epoxy

Steel band only

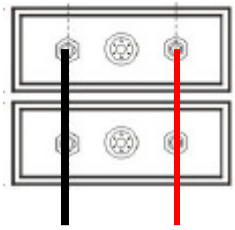
Solid aluminium frame

Alu SS frame in Acrylic box

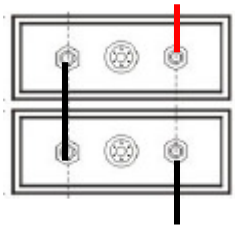
3) Connection of battery cells

4 cells in series = 12 volt nominal (12.8 V)
8 cells in series = 24 volt nominal (25.6 V)
16 cells in series = 48 volt nominal (51.2 V)
24 cells in series = 72 volt nominal (76.8 V)
32 cells in series = 96 volt nominal (102.4 V)

The balancing capacity of a BMS system is usually 1 - 1.5 Amps per cell. So we recommend to use one balancer for up to 200 Amp cell capacity. You can use one balancer for a higher capacity by using larger cells or connect multiple cells in series (have to be similar cells). We do not recommend to use capacities of more than 400 Amp per balancer.



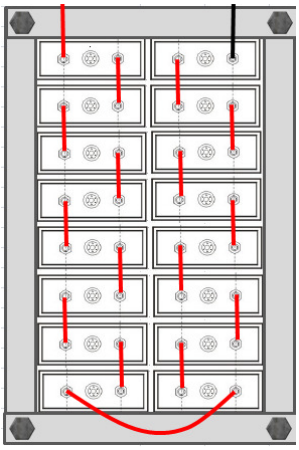
Two 100 Amp 3.2 volt cells connected parallel = 3.2 Volts 200 Amps ONE balancer required



Two 100 Amp 3.2 volt cells connected in series = 6.4 Volts 100 Amps TWO balancers required

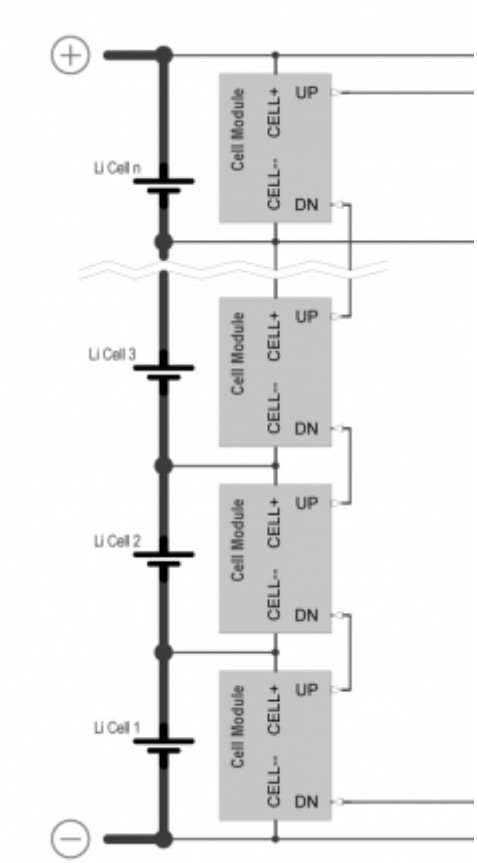
First design your final setup and let us know - we can confirm the number of balancers and material you need and if the setup configuration is correct for your use.

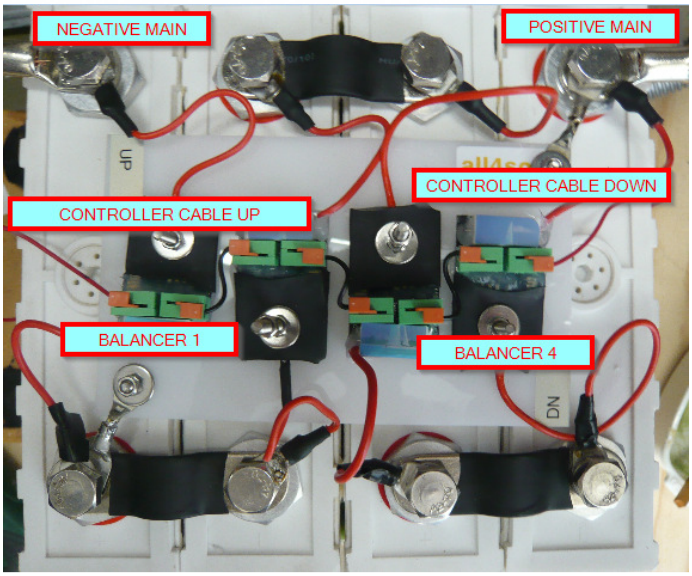
Example for 48 volt battery pack:



4) Connection of balancers

Example for 4 cells in series

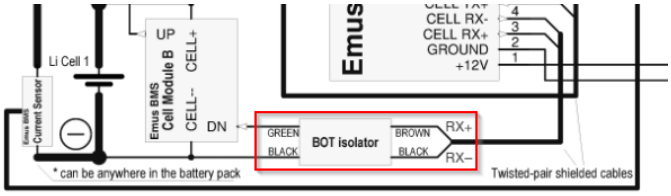




Cable from flat part to negative cell connector and cable besides resistor (white block) to positive cell connector. UP control cable to DN of next balancer etc.

5) Connection of BOT isolators

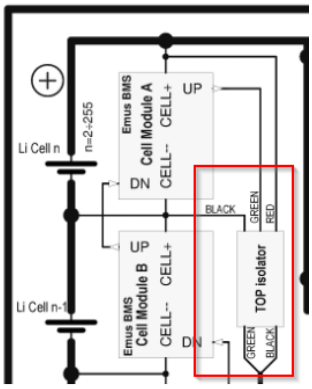
On each end of the battery a BOT isolator has to be installed and connected to the last cell of the string and the BMS controller.



The BOT isolator with the two cables on each side has to be connected to the negative end of the battery string.

GREEN cable to DN connection of last balancer module
BLACK cable to negative of last battery cell

BROWN cable to RX + (connection 3) BMS
BLACK cable to RX - (connection 4) BMS

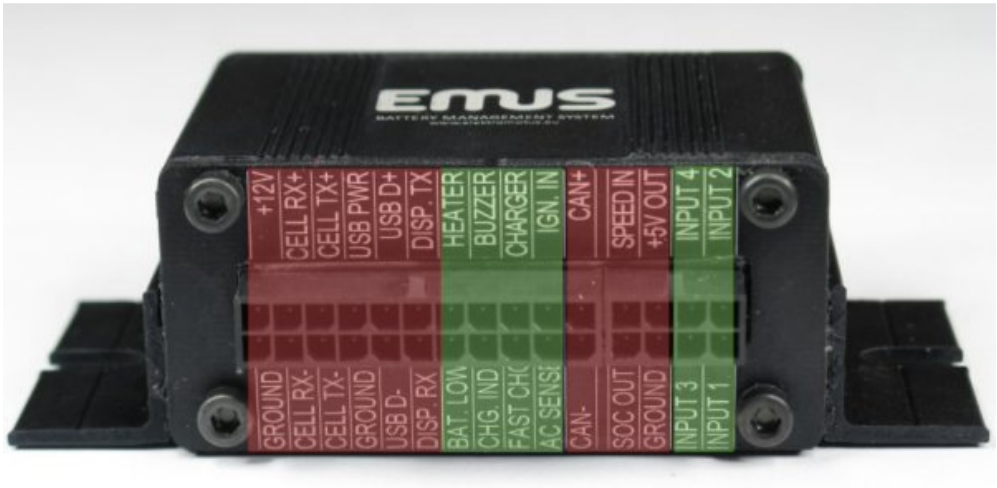


The BOT isolator with the three cables on each side has to be connected to the positive end of the battey string.

GREEN cable to DN connection of last balancer module
BLACK cable to negative of the last battery cell
RED cable to the positive of the last battery cell

BROWN cable to TX + (connection 5) BMS
BLACK cable to TX - (connection 6) BMS

6) BMS connections

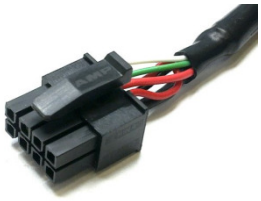


7) Current Sensor

The current sensor senses all current in and out of the battery and enables to display the capacity, usage, charge, discharge etc. on the display.

The current sensor has to be installed within the main power string of the battery.

It is supplied with a cable and a plug that can be directly connected to the BMS controller.

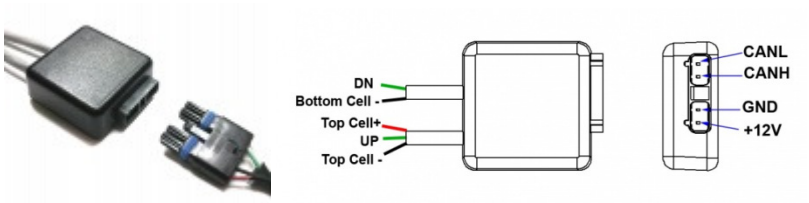


8) CAN cell modules

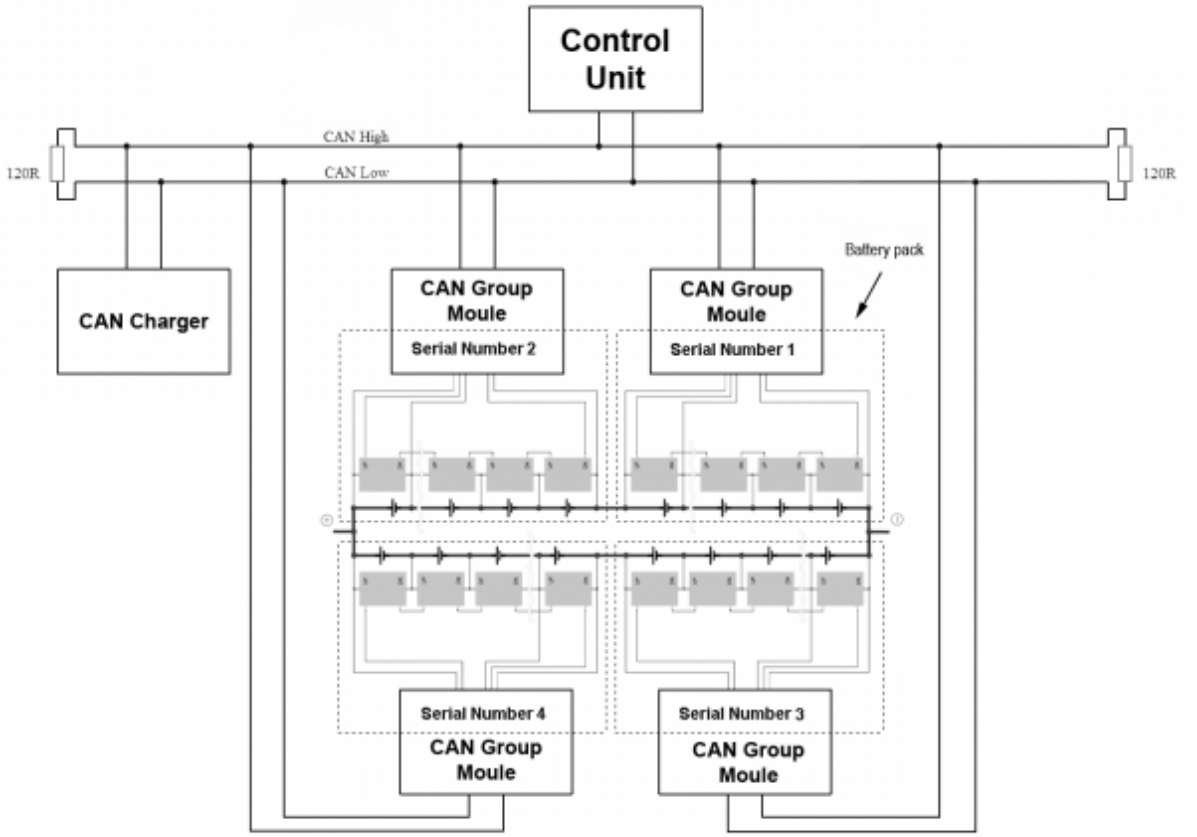
CAN cell modules can connect several battery batteries to one single BMS via CAN bus.

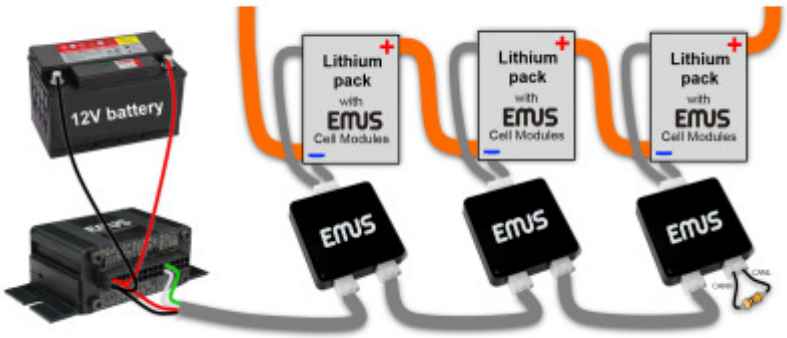
For example:

2 battery banks of 16 x 100 Amp cells = 48 Volts. Each bank has 16 balancers. Both banks require a CAN cell module.



All CAN Group modules are connected to the CAN high and CAN low connection of the BMS controller (see section 6) and to the negative and positive of a 12 V DC power source. The BOT modules are not required.


Control Unit
CAN High
CAN Low
120R
120R
CAN Charger
CAN Group Moule
Serial Number 2
CAN Group Moule
Serial Number 1
Battery pack
Serial Number 4
CAN Group Moule
Serial Number 3
CAN Group Moule


12V battery
Lithium pack with EMUS Cell Modules
Lithium pack with EMUS Cell Modules
Lithium pack with EMUS Cell Modules
EMUS
EMUS
EMUS

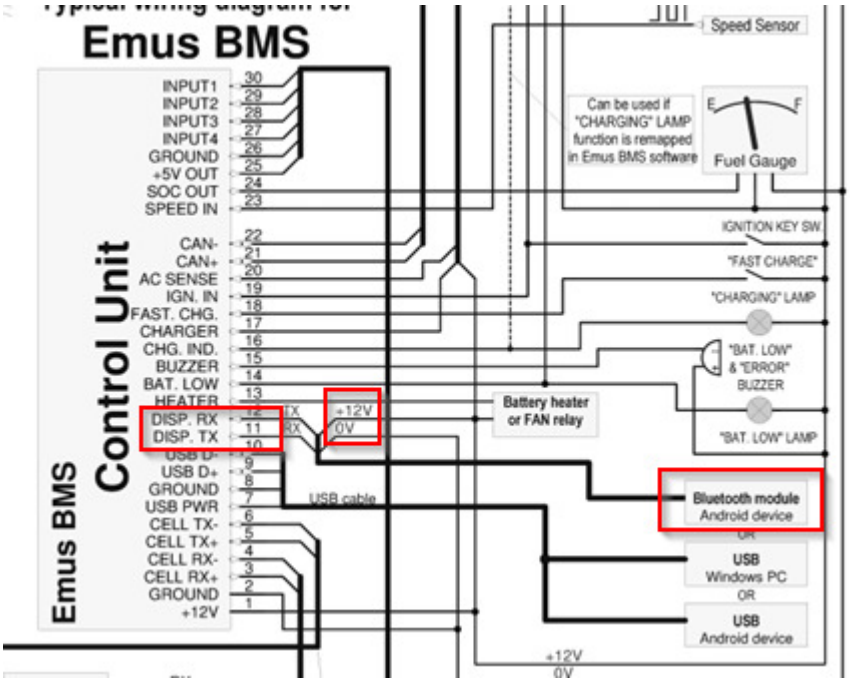
9) Blue Tooth Module

To connect to Android Tablet

Emus Bluetooth module operates from 12V supply and communicates with Emus Control Unit via RS232 port (DISP.TX and DISP.RX pins). Connection is as follows:

1. Black - 0V — BMS controller "GROUND" 12 V negative
2. Red - +12V — BMS controller "USB PWR" 12 V positive
3. White - DISP.RX — BMS controller "DISP.RX" Pin 12
4. Green - DISP.TX — BMS controller "DISP.TX" Pin 11
5. Shield - not connected.

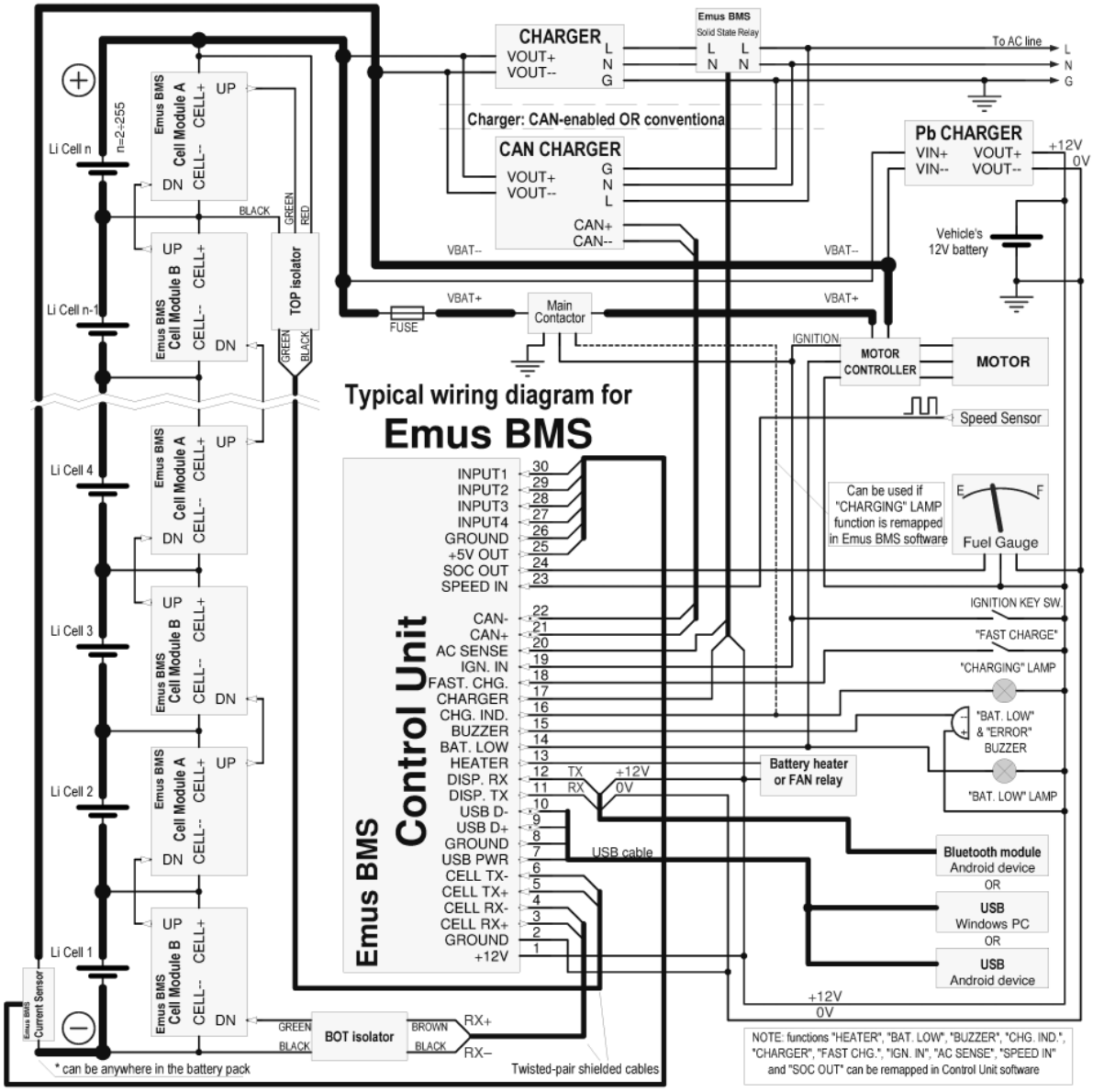
Please note that RS232 port is shared with USB port internally: Bluetooth will be not accessible while USB is connected. Bluetooth module can be powered from ignition key, if energy saving is required.



We recommend to use Android Version 4.x on a tablet like Nexus (Google)

Download the software on the Android device using "Applications / Playstore" search for "Emus EVGUI" - install / pair via Bluetooh with BMS / run the programm
PAIRING PASSWORD with your Android Tablet: 1234

10) Full wiring diagram



11) PC Software

We will supply the latest software with the BMS module. You can install the software on a WINDOWS computer with USB.

Install the CONTROL PANEL SOFTWARE "EMUS BMS.... exe"

Version 1.... if no CAN Group modules are used
Version 2.... if CAN Group modules are used

The EMUS BMS Control Unit connects to PC via USB port and uses VCP (Virtual Com Port) to communicate with the application. VCP requires a special driver, which (executable installer) which will be on the installation CD.

Drivers can also be downloaded here: http://www.ftdichip.com/Drivers/VCP.htm

The latest firmware is installed on the BMS unit.

Introduction to configuration

Once Emus BMS is installed, it must be configured to work properly. Configuration includes various types of parameters from cells count, protection parameters to pins re-mapping.

All configuration parameters have a popup hint tool-tip text which appears when mouse is hovering above the configuration parameter entry element.

Configuration parameters change can be done only in logged in state as described in configuration management section below. When user is not logged in then all configuration parameters and buttons except *Login..* are disabled and grayed out and parameter entry is not possible.

When a parameter is changed its background turns yellow which means that parameter was edited but has not been committed and saved to BMS yet. Committing the parameter is done when user deselects parameter entry field. Once parameter is committed successfully the yellow background is removed. If for some reason the parameter was not committed and it still shows yellow then select and deselect the entry field to try again. **NOTE!:** When charger is connected and charging parameter configuration will be blocked, and yellow background will not be removed.

Configuration management

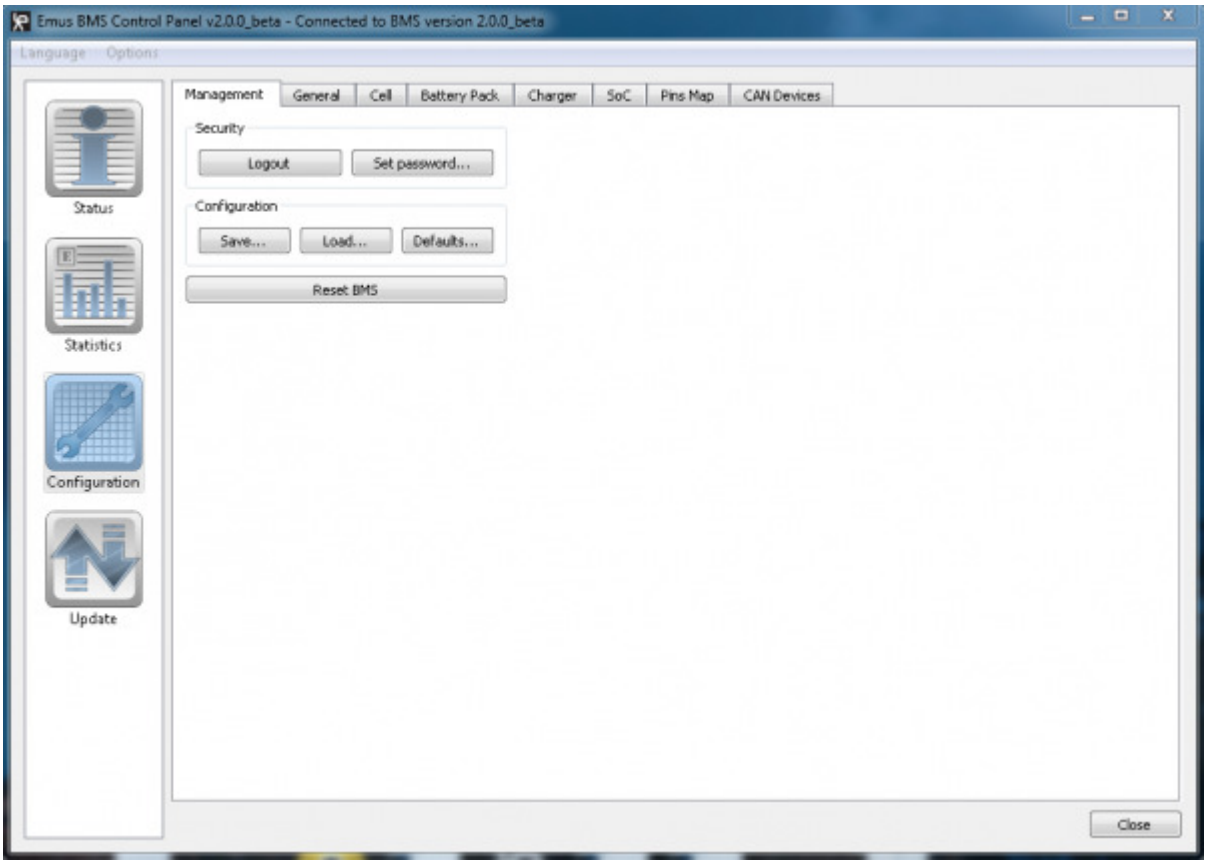
Since version 1.6 configuration of BMS has new features were introduced enhancing usability and the security of parameters.

The password can be set to protect the configuration of BMS from unauthorized change. By default on fresh BMS Control Unit the password is not set and therefore no login is required. The user is always in logged in state when password is not set. The user can set the password using *Set Password...* button and then BMS Control Unit becomes password protected.

NOTE!: that password security has 10 minutes automatic logout period of the user if no configuration activities were made. To enable configuration editing it you would need to log in again.

NOTE!: The login access is locked out after 3 sequential unsuccessful login attempts for 10 minutes. If 3 unsuccessful login attempts were made then user must wait 10 minutes before trying to login again.

The configuration of BMS can also be saved to file, loaded from file and reset to defaults. To perform these operations the user must be logged in to BMS. The configuration management page and its buttons are described below



BMS Control Panel configuration management page

Login... / Logout

Login or logout button. When user is logged out the button shows *Login...* pressing which shows password entry dialog. After entering correct password the button shows *Logout* which indicates successful login. If the login failed the button stays *Login...*. To logout simply press this button when it displays *Logout*

Set password

Sets the password of BMS Control Unit password. The user must be in logged in state to be able to set new password. Password must be from 4 to 8 characters long. If empty password is left and confirmed twice then this disables the password.

Save...

Opens save configuration to file dialog for entering file name to save to. After confirming the file name two questions are asked if user wants to save password and initial SoC value into configuration file. If they are selected then setting SoC and/or password commands are storred into configuration file.

CAUTION!: The password is stored in configuration file as plain text so use this option with care.

Load...

Opens load configuration file dialog for selecting file name to load. It automatically sets the configuration parameters of BMS, sets SoC and/or password (if they were stored in the file) and resets the BMS to work with newly loaded configuration.

Defaults...

If the user confirms to load default configuration then factory default settings are loaded to BMS and it is reset.

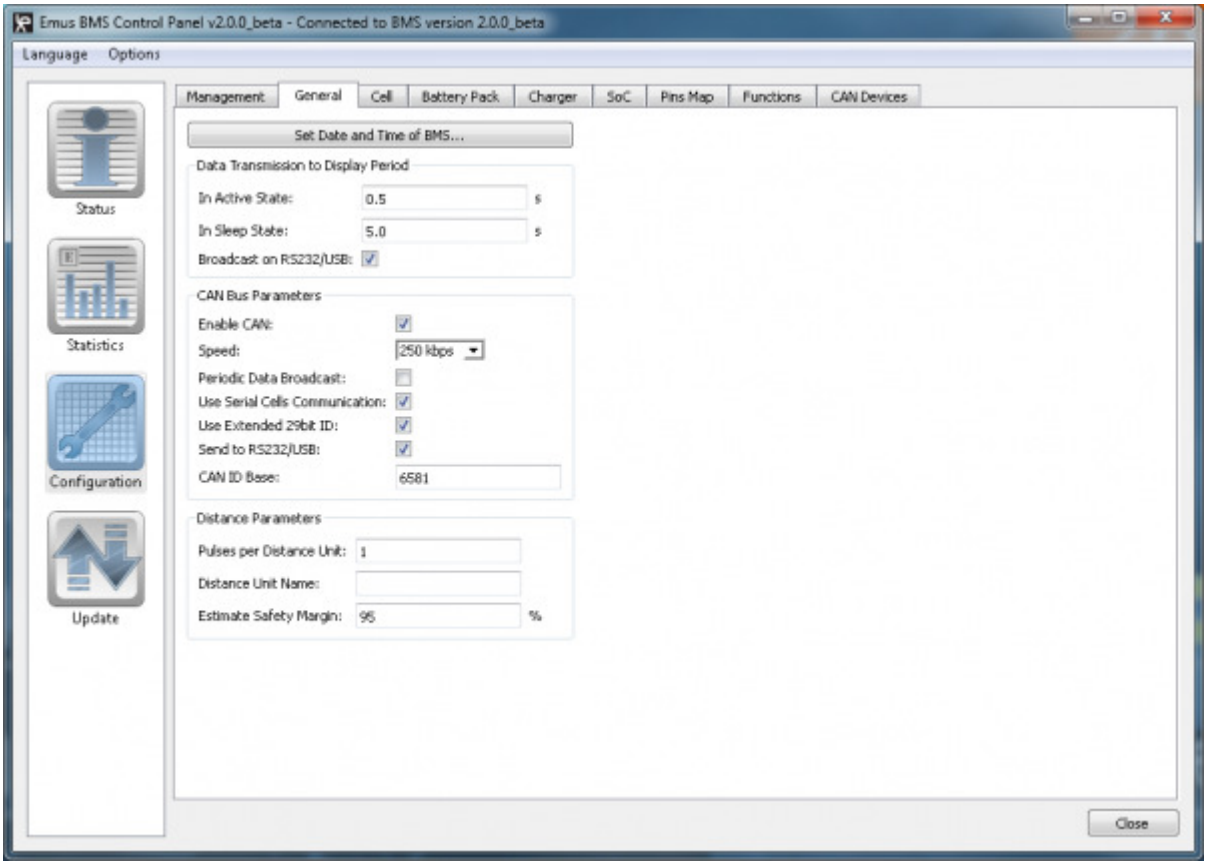
NOTE!: The password is not cleared when loading default settings.

Reset BMS

Does what it says - resets BMS. This operation is sometimes needed when changing configuration parameters requiring fresh BMS start to activate (for example enabling CAN interface).

General configuration

General parameters section allows to configure general parameters for BMS operation. One section describes the timing parameters configuration, another is focused on setting operation of CAN bus, and the last one is for distance parameter configuration. Parameters list are described below.



BMS Control Panel general configuration page

Set Date and Time of BMS...

Sets the date and time of BMS internal clock. The internal clock is used by BMS to record statistics and events timestamps. This clock does not support daylight savings time.

Data Transmission to Display Period In Active State

Display update period which defines the frequency of broadcasting the parameters via RS232/USB interface and/or CAN bus. Active state is when either charger is connected or ignition key on IGN input PF5 is in switched on. This period depends on user's requirements how frequently the BMS operation information is needed to be received. Good starting value is 1 second. Minimum is 0.1s for very frequent updates which would generate and a lot of data for receiving device.

Data Transmission to Display Period In Sleep State

Display update period which defines the frequency of broadcasting the parameters via RS232/USB interface and/or CAN bus. Sleep state is when charger is de-activated and on IGN input is switched off. In sleep state the updates could be very rare like once every minute or similar.

Enable CAN

If the application uses CAN interface then it must be enabled with this option.
NOTE!: A BMS reset is required for change to take effect.

Speed

Sets the bit rate from the selection of 50, 125, 250, 500, 800 and 1000 kbps
NOTE!: When using CAN charger please make sure that this speed matches to CAN charger's speed.
NOTE!: A BMS reset is required for change to take effect.

Periodic Data Broadcast

Periodically broadcasts the special CAN messages of BMS operation parameters over CAN interface if enabled. It uses the data transmission to display periods that are configured above.

Use Serial Cells Communication

Check to use serial cell communication or uncheck to use CAN cell communication.

Use of Extended 29bit ID

Check to use extended 29 bit CAN ids instead of basic 11 bits if enabled. The ID is used for the broadcast CAN messages described above.

NOTE!: This setting does not affect the format of charger specific CAN messages format.

Send to RS232/USB

Enables the transmission of received CAN messages to corresponding serial interface sentences "CN1..." (see serial communication protocol description for exact format). This may be useful if a device connected via serial interface would need to "see" and manage the CAN devices over serial interface.

CAUTION!: This function is not intended to be fully functional CAN/Serial converter because of BMS CAN messages processing and serial interface speed limitations. It could be used when there are not many messages on the CAN network.

CAN ID Base

CAN ID Base address which allows to set an arbitrary base address for periodic broadcast CAN messages generated by BMS. This allows to use several BMSes on the same CAN bus or resolve the possible addressing conflicts with other devices.

For extended 29 bit ID it represents upper 13 bits of ID. For example the default extended ID 6581 is 19B5h in hexadecimal and BMS broadcast the messages starting from 19B50000h and so on.

For basic 11 bit ID it this a base address number which must be added to the broadcasted messages IDs. For example if this number is entered 800 then BMS will broadcast messages with standard 11 bit IDs starting from 800.

Pulses per Distance Unit

Sets the number pulses that are required to be registered on SPEED IN input to count one distance unit. For example if your car's service manual says that gearbox VSS (Vehicle Speed Sensor) is producing 600 pulses per one kilometer then you should enter value of 600 for BMS to measure the distance in kilometers and speed in kilometers per hour.

Distance Unit Name

Allows to set the distance unit name for easier display in status screens and for further reference. Name can be up to 2 characters long.

Estimate Safety Margin

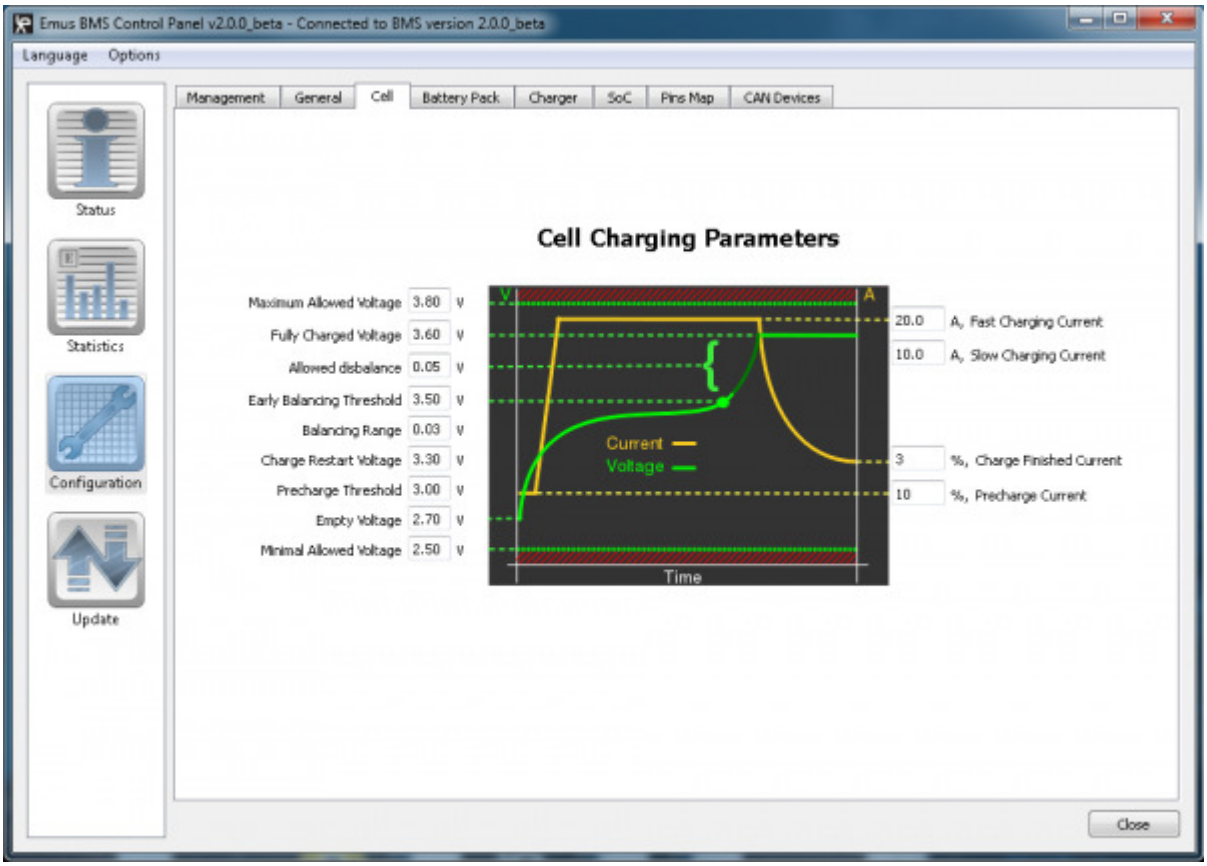
Defines the percentage of battery capacity to subtract from left capacity that is used estimated remaining distance calculation. Recommended value is around 10% but may depend on application.

Cells configuration

Emus BMS is designed to work with wide range of battery cells with operating voltages in between 2 and 5 V, including LiPO, Li-Ion, LiFePO4 and others. Different cell types operate at different voltages and these parameters must be set for proper operation of Emus BMS.

To configure cell type, connect the Emus BMS Control Unit to PC's USB port, start the Emus BMS Control Panel application and navigate to *Configuration* page, *Cells* tab. For

visual reference of the cell parameters, most of them are aligned to an image of a cell charging curve.



BMS Control Panel Cells configuration page

Max Allowed Voltage

Sets the critical maximum never-exceed voltage of the cell that is specified by cell's manufacturer. If *Over-Voltage Cutoff* function is enabled the protection is engaged via pin with function PF12 assigned when some cell voltage exceeds this setting.

If BMS is charging it aborts charging with corresponding error code.

Additionally BMS records under-voltage event and updates the according statistic.

Fully Charged Voltage

The voltage which indicates that cell is fully charged and has 100% SoC. This setting should be configured according to cell manufacturer's specification maximum voltage in normal usage conditions. It should have some margin below critical maximum never-exceed voltage stated by cells manufacturer. BMS uses this value as a reference for calculations of 100% SoC.

When charging BMS uses this setting as the target voltage needed to reach with all cells in balanced condition. When charging is finished all cells in the pack should have the voltages close this setting.

Allowed Disbalance

Sets allowed dis-balance voltage which defines what is the minimum difference between lowest and highest cell voltages. When actual cells difference exceeds this setting cells are considered out of balance and early balancing function is engaged during main charging stage. Early balancing function is engaged when cells voltage exceeds *Early Balancing Threshold* parameter.

Early Balancing Threshold

Sets the early balancing threshold voltage above which the early balancing starts. It balances the cell charge differences while exceeding the configured *Allowed Dis-balance* threshold. Early balancing is used during main charging stage when charge current is kept constant.

Balancing Range

This is the voltage margin below *Fully Charged Voltage* parameter in which the balancing of the cells is done when a non-CAN charger (charger not capable to adjust current according to BMS command) is used in balancing stage. BMS periodically balances down the cells voltages and charges them again within this range below *Full Charged Voltage* parameter until all cells are equally balanced. **NOTE!:** This parameter does not correspond to any point on the cell charging curve.

Charge Restart Voltage

Sets the voltage threshold, below which charging is restarted if charger is connected. **NOTE!:** This parameter does not correspond to any point on the cell charging curve.

Pre-Charge Threshold

Cell's voltage threshold for selecting pre-charge or normal charging mode. It is useful when a charger with controllable current (like most chargers with CAN inteface) is used to charge deeply discharged cells. When the minimum cell's voltage is below this threshold BMS uses small pre-charge current to charge the pack. When minimum cell voltage exceeds this threshold BMS selects normal charging current depending on Slow/Fast current setting of charger configuration parameters. Setting this parameter to very low value (like 2.0V) disables the pre-charging feature.

Empty Voltage

The voltage which indicates that cell is fully discharged and has 0% SoC left. This setting should be configured according to cell manufacturer's specification minimum voltage in normal usage conditions. It should have some margin above critical minimum never-drop-below voltage stated by cells manufacturer. BMS uses this value as a reference for calculations of 0% SoC.

Minimal Allowed Voltage

Sets the critical minimum never-drop-below voltage of the cell that is specified by cell's manufacturer. Below this voltage the protection is engaged by disconnecting battery contactor via pin which has pin function PF12 assigned (if activated). For this protection to work *Under-Voltage Cutoff* function must be enabled and battery protection contactor connected to output pin which has PF12 function assigned.
If BMS is charging it aborts charging with corresponding error code.
Standard value for LiPO and Li-Ion cells is around 3.0V ; for LiFePO4 – 2.5V. Please use cells manufacturer's datasheet to get exact needed value.
Additionally BMS records under-voltage event and updates the according statistic.

Fast Charging Current

This setting configures the fast charge current for CAN chargers when Fast Charge selection input with function PF2 assigned is active and the charger can be used at its full available power.

Slow Charging Current

This setting configures the slow charge current for CAN chargers when Fast Charge selection input with function PF2 assigned is inactive. This slow charge allows to charge the vehicle from lower power electrical sockets. For example some 230V sockets could be rated 10A which would require to charge the battery with lower current than when charged from 16A socket.

Charge Finished Current

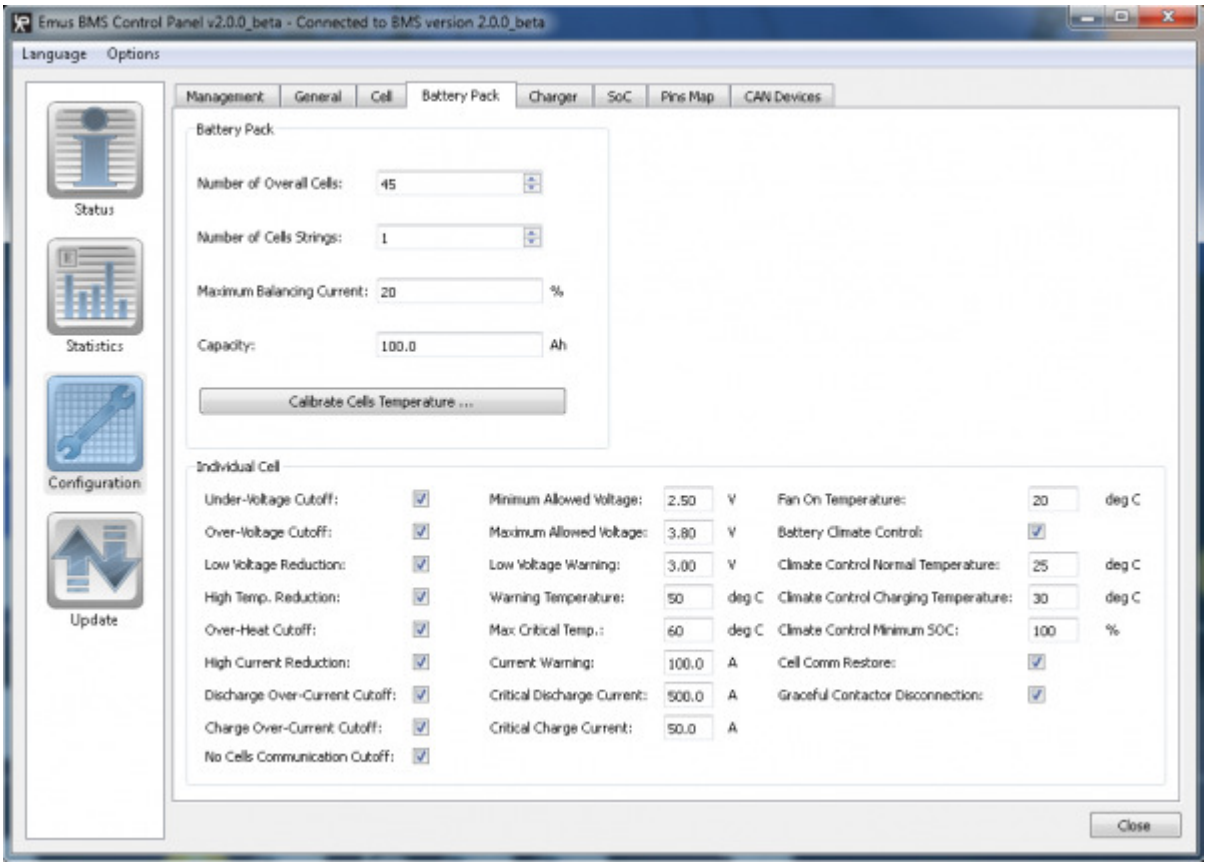
This setting defines what should be the minimum set current for CAN charger in balancing stage. BMS starts gradually decreasing the requested current from charger when cells reach the *Fully Charged Voltage* setting. If the cells are balanced and current has decreased to this point, charging is considered finished. This current is set as a percent of the nominal charging current, which can be either Fast Charging Current or Slow Charging current.

Pre-charge Current

Allows to setup the pre-charge current for CAN chargers when cells that are deeply discharged below *Pre-charge Threshold* voltage. This current is set as a percent of the nominal charging current, which can be either Fast Charging Current or Slow Charging current, and is used during Pre-charging stage. When the pre-charge voltage threshold is exceeded BMS goes to the next main charging stage.

Battery Pack configuration

Battery pack parameters allows you to set the configuration of the whole battery pack, and to set thresholds for various battery pack protection features. These parameters are described in detail below.



BMS Control Panel Battery Pack configuration page

Number of Overall Cells

The total number of cells that you have in your battery pack. The battery pack may consist either of one string of cells connected in series, or several of these strings connected in parallel. This setting allows BMS to verify if it has detected correct number of cells and if the communication with cells is ok. It will raise an alert and

engage other protection functions if the actual number of cells does not match this setting.

Number of Cells String

This parameter sets the number of parallel strings. It is used when calculating the charge voltage for a controlled charger, and when displaying individual cell parameters.

Max Balancing Current

Sets the maximum allowed balancing current of the cell modules to reduce dissipated heat during balancing stage. Reduce this value if cell modules temperature is getting too high during balancing stage. Cell modules can work in balancing mode without communication to Control Unit and will not exceed this setting.

When charging Control Unit reduces maximum balancing current when needed even further to not exceed Warning Temperature.

Capacity

Defines the nominal capacity of the cell. This parameter is used in State of Charge (SoC) calculation to determine the SoC level. If you are using sever parallel strings of cells, multiply the cell capacity by the number of parallel strings for correct state of charge calculation.

Calibrate Cells Temperature...

Sends the calibration command to cell modules to set the temperature value on all modules to temperature on the right as reference. This needs to be done only once when all modules are installed and are at the same temperature conditions.

Under-Voltage Cutoff

Engage the battery protection contactor in case of under-voltage by using output pin with function PF12 assigned when lowest cell voltage drops below *Min Critical Voltage parameter* value.

Minimum Allowed Voltage

The same parameter as in Cells configuration tab. For more detail, see Cells configuration above.

Fan On Temperature

Sets the temperature threshold above which BMS enables fan (or other battery pack cooling device) output on pin with PF13 function assigned. Set this temperature to ensure the optimal cells operation temperature range in hot climate conditions or intense battery use. **NOTE!:** Fan will be enabled when this temperature is reached regardless of whether the battery climate control is enabled or not.

Over-Voltage Cutoff

Enables the battery cutoff contactor in case of over-voltage (when voltage exceeds *Max Critical Voltage* parameter value) by using pin with function PF12 assigned.

Maximum Allowed Voltage

The same parameter as in Cells configuration tab. For more detail, see Cells configuration above.

Battery Climate Control

Enables the battery climate control feature, which controls the battery temperature using heater output pin PF5 (if assigned), and fan output pin PF13 (if assigned).

Low Voltage Reduction

Enables power reduction output on pin with function PF16 if some cells voltage drops below *Low Voltage Warning* parameter level.

Low Voltage Warning

Sets the low voltage threshold reaching which causes Low Voltage indicator on pin with function PF8 assigned warning. Periodic blinking shows that some cell with

minimal volage has dropped below this low voltage threshold. When this indicator is constantly on then the average voltage of whole pack cells has decreased below this setting. In general use this is a voltage threshold at which alarm (light/buzzer) will start during discharge state (when driving, operating, etc.). This value highly depends on battery cell type and manufacturer and should be chosen from discharge graph in manufacturer's datasheet. Usually for Li-Ion/LiPO cells it is around 3.6V and for LiFePO4 – around 3V. To get the warning sooner, increase this value.

If *Low Voltage Reduction* function is activated then signal on output pin with function PF16 assigned is activated which can be used for vehicle's motor controller to reduce the power.

BMS also records a low voltage warning event and updates corresponding statistic counter.

Climate Control Normal Temperature

The battery temperature which will be maintained when not charging if battery climate control is enabled. If the average temperature measured by the cell modules drops below this threshold, heater output pin PF5 (if assigned) will be enabled, and if the average temperature is above this threshold, fan output pin PF13 (if assigned) will be enabled.

High Temp. Reduction

Activates power reduction output pin with function PF16 assigned when maximum cell temperature exceeds warning level specified by *Warning Temperature* parameter.

Warning Temperature

Sets the temperature threshold above which BMS indicates warning and activates power reduction if *High Temp. Reduction* function is enabled and pin with function PF16 is assigned.

During charging the balancing current of cell modules is gradually reduced when max cells temperature starts exceeding this threshold because during charging the temperature increase usually caused by shunts on cell modules when balancing.

BMS also records a high temperature warning event and updates corresponding statistic counter.

Climate Control Charging Temperature

The battery temperature which will be maintained when charging if battery climate control is enabled. If the average temperature measured by the cell modules drops below this threshold heater output pin PF5 (if assigned) will be enabled, and if the average temperature is above this threshold, fan output pin PF13 (if assigned) will be enabled.

Over-Heat Cutoff

Cutoff the battery contactor in case of maximum cell temperature exceeding *Max Critical Temp.* value by using activating the output pin with function PF12 assigned.

Max Critical Temp.

Sets the maximum allowed temperature in degrees of Celcius of cell modules. If this temperature is reached on some cell module then BMS switches off the charging and indicates an error.

This parameter depends on battery type. For most lithium-based cells it is around 60°C. This value is not a strict one, but hence that the higher the temperature, the shorter battery life is. Usually LiFePO4 cells start to degrade much faster when used at temperatures above 45-50°C and most LiPO/Li-Ion cells, in addition to shorter life, can catch fire if operated above 60°C. If any cell in the battery pack reaches specified temperature, load and charger are disconnected and error code shown. Use this setting responsibly.

If *Over-Heat Cutoff* function is enabled then battery protection contactor is engaged via output pin with function PF12 assigned.
Additionally BMS records over-heat protection event and updates the according statistic.

Climate Control Minimum SOC

Minimum battery state of charge value, below which battery climate is no longer controlled even if enabled, to prevent deep discharge.

High Current Reduction

Activates power reduction output pin with function PF16 assigned when discharge current exceeds warning level specified by *Current Warning* parameter value.

Current Warning

Sets the warning discharge current above which BMS enables buzzer warning (output pin function PF7) and power reduction (output pin function PF16) if *High Current Reduction* function is enabled.
Additionally BMS records discharge high current warning event and updates the according statistic.

Cell Comm Restore

If this function is enabled, when cells are deeply discharged and there is either no cell communication or an undervoltage event has occurred and a charger of any type has been connected, no charging error will be registered for 30 seconds to charge the battery a bit to restore cell communication and to raise cell voltages enough for normal charging.

Discharge Over-Current Cutoff

Cutoff the battery protection contactor on output pin with function PF12 assigned in case when discharge current exceeds the *Critical Discharge Current* parameter setting.

Critical Discharge Current

Sets the critical discharge current above which BMS engages protection function by disconnecting the contactor relay on output pin with function PF12 assigned if the *Discharge Over-Current Cutoff* function is enabled.
Additionally BMS records discharge over-current protection event and updates the according statistic.

Graceful Contactor Disconnection

If this function is enabled, and an undervoltage event has occured, the battery contactor will not be disconnected instantly if discharge current is higher than 5 A, to prevent damaging the contactor, but delayed up to 10 seconds to wait for undervoltage reduction to take effect, or the load to be manually disconnected/reduced.

Charge Over-Current Cutoff

Cutoff the battery protection contactor on output pin with function PF12 assigned in case when charge current exceeds the *Critical Charge Current* parameter setting.

Critical Charge Current

Sets the critical charge current above which BMS engages protection function by disconnecting the battery protection contactor relay on output pin with function PF12 assigned if *Charge Over-Current Cutoff* function is enabled.
Additionally BMS records charge over-current protection event and updates the according statistic.

No Cells Communication Cutoff

Enables the cutoff of battery protection contactor on output pin with function PF12 assigned in event of loss of cells communication for over 10 seconds.

Minimum Charging Temperature

Sets the minimum allowed charging temperature in degrees of Celcius of cell modules. If the minimum cell temperature is below this value and charger is connected then BMS starts with pre-heating stage which enables heater output pin Pin Function 5 (PF5) (if enabled) that is controlling external heater which should be heating up the cells until they reach this minimum temperature. As most of Lithium chemistry cells are sensitive to charging in low temperatures, charging should be done in above-zero temperatures. To be on the safe side, set a value of, say, 2°C, to give it a little margin of error. EMUS BMS will turn on the battery heater (if one exists and controlled via PF5) and wait until cell temperatures reaches the value set, before charging the pack.
To disable pre-heating and charge delay, enter a value of -100°C.

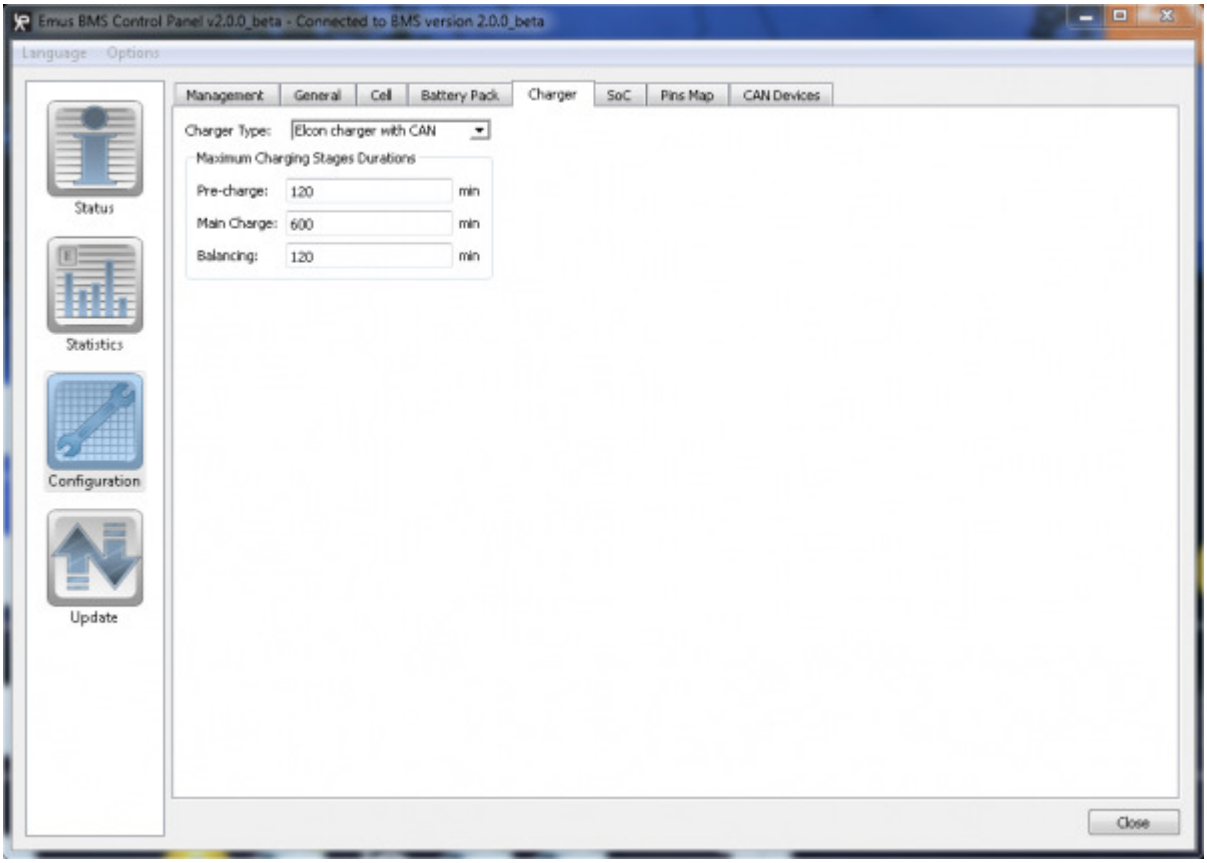
Charger configuration

Emus BMS supports operation using non-CAN and CAN chargers. Non-CAN charger is basically the charger which has no digital data transfer capability over CAN line and can be controlled by only switching it on or off via relay or contactor. CAN charger is the charger which can communicate and can be controlled via CAN communication bus. There is no unified and widely accepted charger communication specification standard and therefore the support of various manufacturers and models is being added to the supported chargers list gradually.

At the current moment Emus BMS supports Elcon chargers that are produced by Hztiecheng.

However the number of supported chargers will soon grow to more models: Brusa NLG5, new Zivan line, NetGain are coming soon.

The charger parameters are configured via charger configuration tab.



BMS Control Panel charger configuration page

Charger Type

Allows you to select the charger type that is controlled by BMS. It may be non-CAN charger which is controlled via the relay using output pin with function PF10 assigned. The sensing that charger is connected to some power supply is made via input pin which has PF3 function assigned. Chargers of this type do not allow BMS to control the charging current and therefore perform somewhat worse as exact optimal current mode cannot be selected as it depends on only how the charger was setup. When CAN type charge is selected then all communication is done via the CAN bus using special messages compliant to specific charger type. For this type of chargers BMS selects optimal charging current and target voltage for different stages of charging.

Maximum Pre-charge Stage Duration

Sets the maximum allowed to time for pre-charge stage with CAN charger to allow cells to reach the *Pre-charge Threshold* voltage and enter normal charging stage. If this time is exceeded a charging error is raised and charging is stopped. Default 2 hours value should be more than enough in most scenarios. If this time is exceeded it usually indicates some issue with the battery.

Maximum Main Charge Stage Duration

Sets the maximum allowed to time for main charge stage to allow cells to reach the *Fully Charged Voltage* and enter balancing stage. If this time is exceeded a charging error is raised and charging is stopped. The time for charging the cell depends on capacity of cells and charging current. Default 10 hours setting should work in most cases.

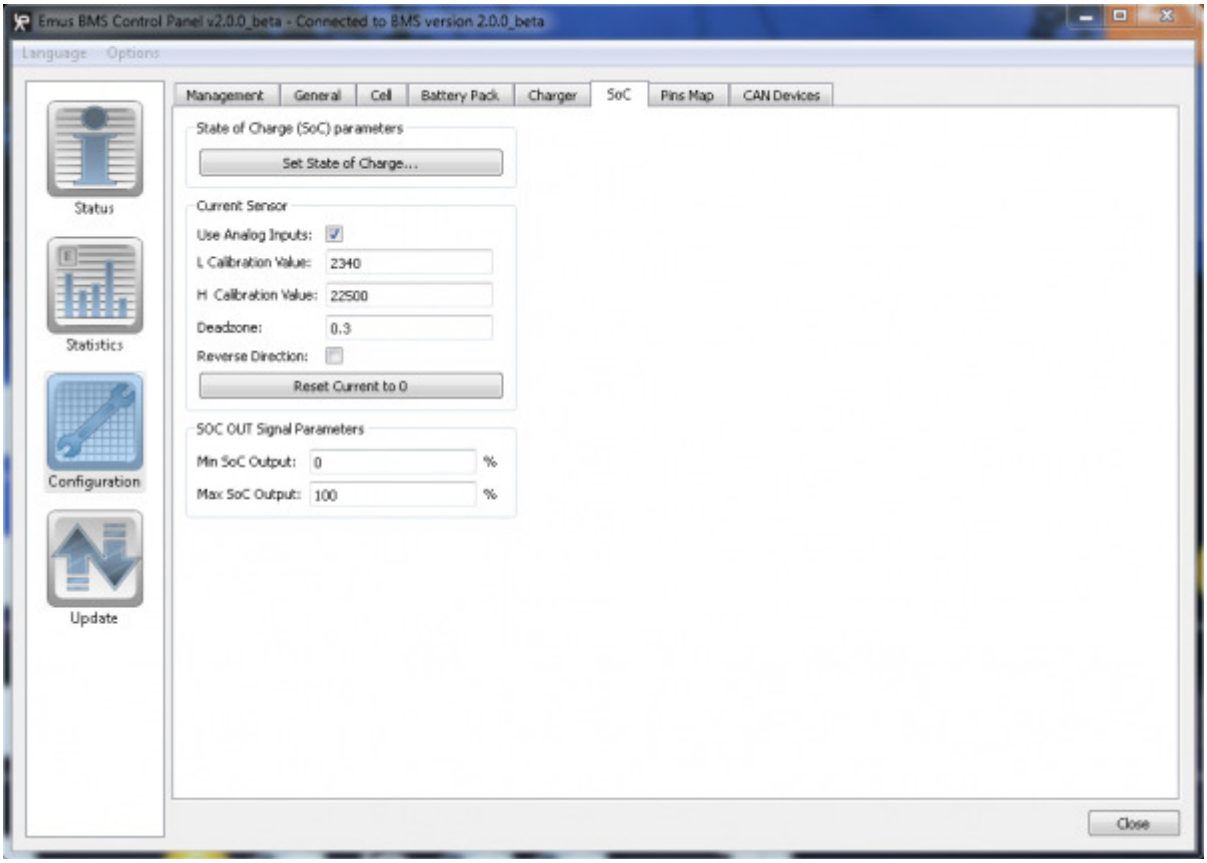
If, for example, total cell capacity is 100 Ah and the pack is being charged with current of 20 A, the pack should be fully charged in 5 hours. Give it a bit of reserve

and set, say, 7 hours (420 minutes). Too long charging time may indicate a bad cell and big energy leak (heat) in the battery pack. If the problem occurs, check cell voltages on Status page, *Cells* tab.

Maximum Balancing Stage Duration

Sets the maximum allowed to time for balancing stage to allow cells to reach the balanced state and complete the charging cycle. If this time is exceeded a charging error is raised and charging is stopped. The time for balancing the cell depends on capacity of cells, disbalance and other parameters. Default 2 hours setting should work in most cases but it sometimes might require longer time when the pack is deeply disbalanced.

SoC configuration



BMS Control Panel SoC configuration page

Set State of Charge...

Sets initial state of charge of the pack. When pressed it prompts to enter the current estimated SoC % of the pack. This function is useful if the initial SoC value needs to be set when installing fresh battery pack with BMS as by default BMS assumes 0% SoC as it has not observed the pack's behaviour during charging and use yet.

It is also possible to save the initial SoC value in configuration file. Then it is set when configuration file is loaded.

L Calibration Value, H Calibration Value

These values are the gain calibration values of the current sensor which are written on the back label of the sensor. Calibration values differ from sensor to sensor.

Deadzone

This is the dead zone of the current sensor reading to improve 0 current stability. This allows to eliminate the SoC drift over time due to electric or magnetic noise of current sensor surrounding media and other factors.

Use small values up to around 10. A default value 3 is good starting point. If sometimes the reading shows tendency to show small current in either direction when actually no current is flowing then *Reset Current to 0* should be used first and additionally this *Deadzone* could be increased.

Reverse Direction

Reverses the direction of current sensor. Use this setting to ensure positive current reading when charging and negative current reading when discharging.

Reset Current to 0

Resets current sensor reading to zero to compensate for sensor's offset and surrounding static magnetic influence.

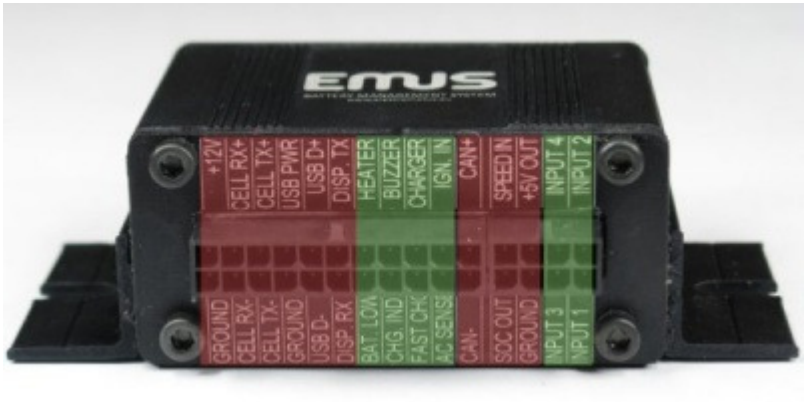
Min SoC Output

Sets the SOC OUT output PWM signal duty period % which corresponds to 0% SoC. This setting is useful when analog fuel gauge is used for displaying the SoC. As analog sensors have some range in which they show values of Empty at some voltage above 0. Therefore, for example, it might be required to define a value of 10% SOC OUT PWM signal to display a SoC value of 0%.

Max SoC Output

In similar way as described above it is set to define the PWM signal duty period % which corresponds to 100% SoC charge estimated by BMS. As a result the SOC OUT PWM signal duty cycle will swing from Min and Max values for displaying 0% and 100% SoC accordingly.

Pins Map configuration

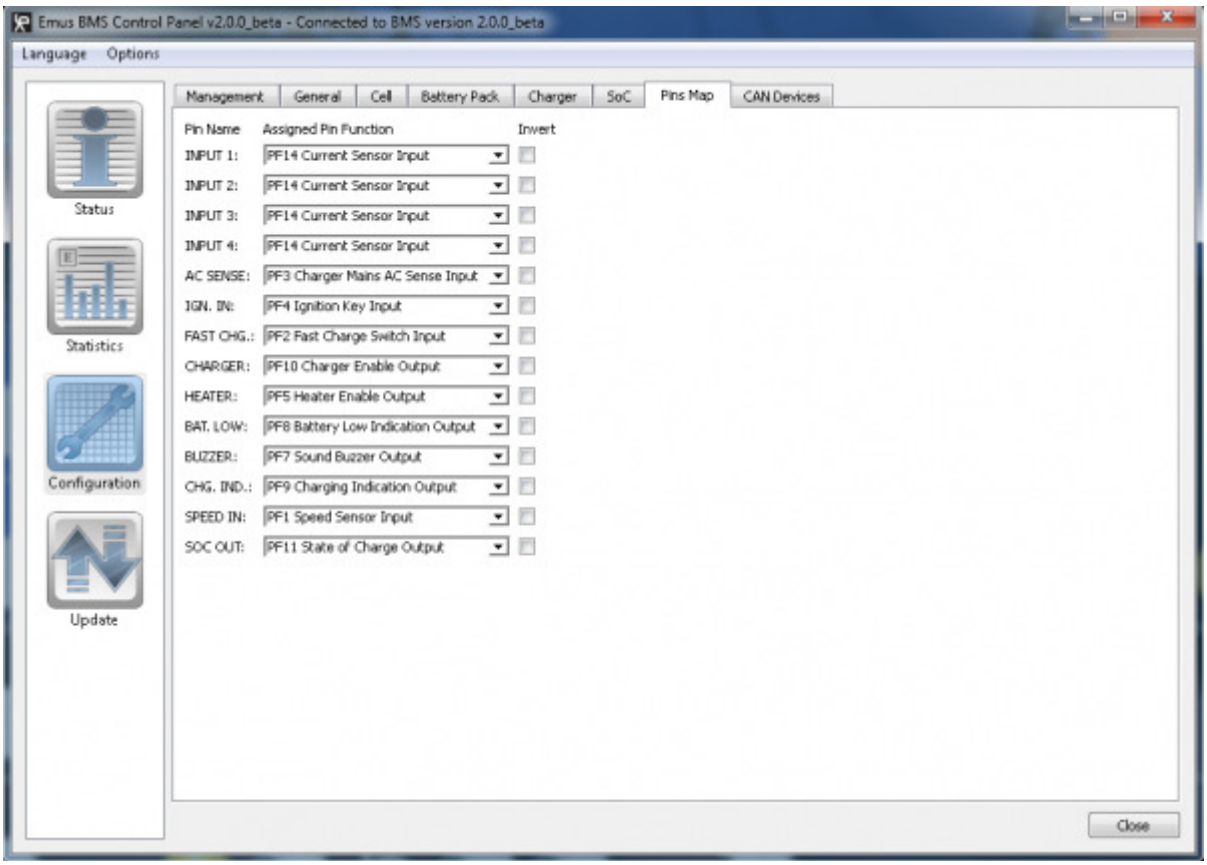


BMS control unit pins

Pins map configuration allows to assign different functions to different pins of BMS Control Unit. This is useful for various installations which don't use all the default pins.For example in hot climate areas battery heater is not needed and cooling fan would be required. Then this function may be assigned to HEATER pin and BMS would control the fan via this pin.

In the picture of Emus BMS Control Unit connector remappable pins are marked in **green** and non-remappable ones marked in **red**.

Different pins have different hardware interfaces. HEATER, BAT. LOW, BUZZER, CHG. IND. and CHARGER pins are open drain outputs that can drive the pin to the ground with maximum 0.5A current. These pins cannot be assigned to input functions. FAST. CHG., AC SENSE, IGN. IN, SOC OUT, SPEED IN and INPUT 1-4 are small power pins that can be assigned either to inputs or small power outputs of static signals. SOC OUT pin also has the possibility to assign specific State of Charge PWM output function which generates signal for displaying SoC to external display devices. SPEED IN has the capability to count the number and frequency of external incoming speed sensor pulses. INPUT 1-4 may be used for current sensor measurements. Please note that if any of INPUT 1 to 4 pin has the *PF14 Current Sensor Input* assigned then all other INPUT pins must be assigned to this function as well because current sensor uses all 4 INPUT pins to dual range current sensing. When this function is selected and committed the control unit automatically updates other INPUT pin functions. When some INPUT function is changed to something else from *PF14* then other INPUT pins have this function removed as well.



BMS Control Panel pins re-map configuration page

Not all pins can be assigned to all functions and the best is to see what configuration options each pin has on the BMS Control Panel software.

In the Pins Map configuration page each remappable pin is listed with function that is assigned to it and along with inversion flag. Each function assignment drop down box has a list of choices of functions that are possible to assign to each pin. The first choice on top of the list is always a default pin function and is assigned when factory defaults are loaded. Other assignable functions choices depend on hardware capabilities of each pin. The last choice *PF0 No Function* disables any function of the pin.

NOTE!: To ensure correct pins operation please make a *BMS Reset* after configuring pin functions.

The list of pin functions is described below:

PF0 No Function
: Disables any function of the pin.

PF1 Speed Sensor Input
: Sets the pin to receive speed sensor pulses to determine the speed and distance of the vehicle. This function can only be assigned only to SPEED IN pin. (Please note that speed and distance function is not enabled in BMS software yet)

PF2 Fast Charge Switch Input
: Sets pin to act as an input for a charge rate switch. If the *Invert* flag is not set then 0V voltage of this pin will be treated as slow charge setting while voltage more than 5V will be treated as Normal/Fast charge choice. This pin can be connected to +12V signals directly.

PF3 Charger Mains AC Sense Input
: Sets pin to act as a sense for non-CAN charger connection to AC mains or other source and as a command to BMS to start and control the charging process. This input may be used with Charger Control Relay supplied by JSC Elektromotus or input from other signal. With inversion flag off 0V - charger is not connected to AC mains and >5V charger is connected to power source and charging should start.

PF4 Ignition Key Input
: Input for ignition key of the vehicle which controls the power state of BMS if it is driven or in idle state. 0V - vehicle idle, >5V - vehicle is in active driving state. Cells poll and display communication rate are depending on this sleep and active state. Active state is also considered when CAN or non-CAN charger is connected to mains regardless of Ignition Key position. In addition this state information is used by graphical interface device such as EVGUI for Windows Mobile or Android to switch the screen on or off automatically when ignition key is switched on or off.

PF5 Heater Enable Output
: This pin function is active when BMS enters pre-heat stage if the battery pack's temperature is below minimum *Heater On Temperature* setting. If this function is assigned to open drain output then in active state the pin is pulled low to the GROUND pin. On other types of pins the active state is +5V on the output.

PF7 Sound Buzzer Output
: Designed to sound a sound buzzer for driver in case of warning or error.

PF8 Battery Low Indication Output
: An indicator lamp for driver informing that battery is getting low starting blinking and when battery is very low it is always on.

PF9 Charging Indication Output
: An indicator lamp for driver to show various stages of charging process. When it is off charger is not connected. When it is displaying one to several pulses in around 2 seconds intervals it indicates that charging is ongoing where number of pulses means the charging stage: 1 pulse - pre-heat, 2 - pre-charge, 3 - main charge, 4 - balancing. When charging is finished ok it displays this by constant indicator on with short interrupts every few seconds. A charging error is indicated by rapid flashing.

PF10 Charger Enable Output
: Output which controls the non-CAN charger during charging process. When charger is connected to AC mains or other power source this must be inidicated to BMS by

activating *PF3 Charger Mains AC Sense Input*. Then BMS enables the charger activating this *PF10 Charger Enable Output*. During balancing stage BMS may periodically enable and disable the charger until all cells in the pack are balanced. Once charging is complete BMS disables the charger.

PF11 State of Charge Output

This is the Pulse Width Modulation output signal which has TTL levels of 0 and +5V switched at base frequency of 7.8kHz. The width of the pulse is controlled from 0 to 100% duty by the value of State of Charge. This signal may be converted to analog voltage by filtering it with externally attached > 1uF capacitor between the pin and ground. This analog voltage may be measured voltage meter which is graded to display fuel levels. Alternatively this pin ouptut may control a MOSFET gate to drive fuel gauges which require higher current and work on principle of measuring a resistance to the ground which is common in many cars fuel tank gauges. Due to the specific nature of this function it may only be assigned to SOC OUT pin.

PF12 Battery Contactor Output

This is a battery protection contactor outptut which disables the battery in the event of protection error configured on BMS. For information about protection functions configuration look at Cells configuration section.

PF13 Battery Fan Output

This output is enabled once the maximum cell temperature of battery pack exceeds the *Fan On Temperature* setting of Cells configuration. This function pin may drive a fan or other battery pack cooling device.

PF14 Current Sensor Input

Current sensor input which uses all pins from INPUT 1 to INPUT 4 together to work with analog dual range current sensor. If at least one INPUT X pin is changed to this function other INPUT pins are changed to this function as well. As this is specific function it may only be assigned to INPUT X pins.

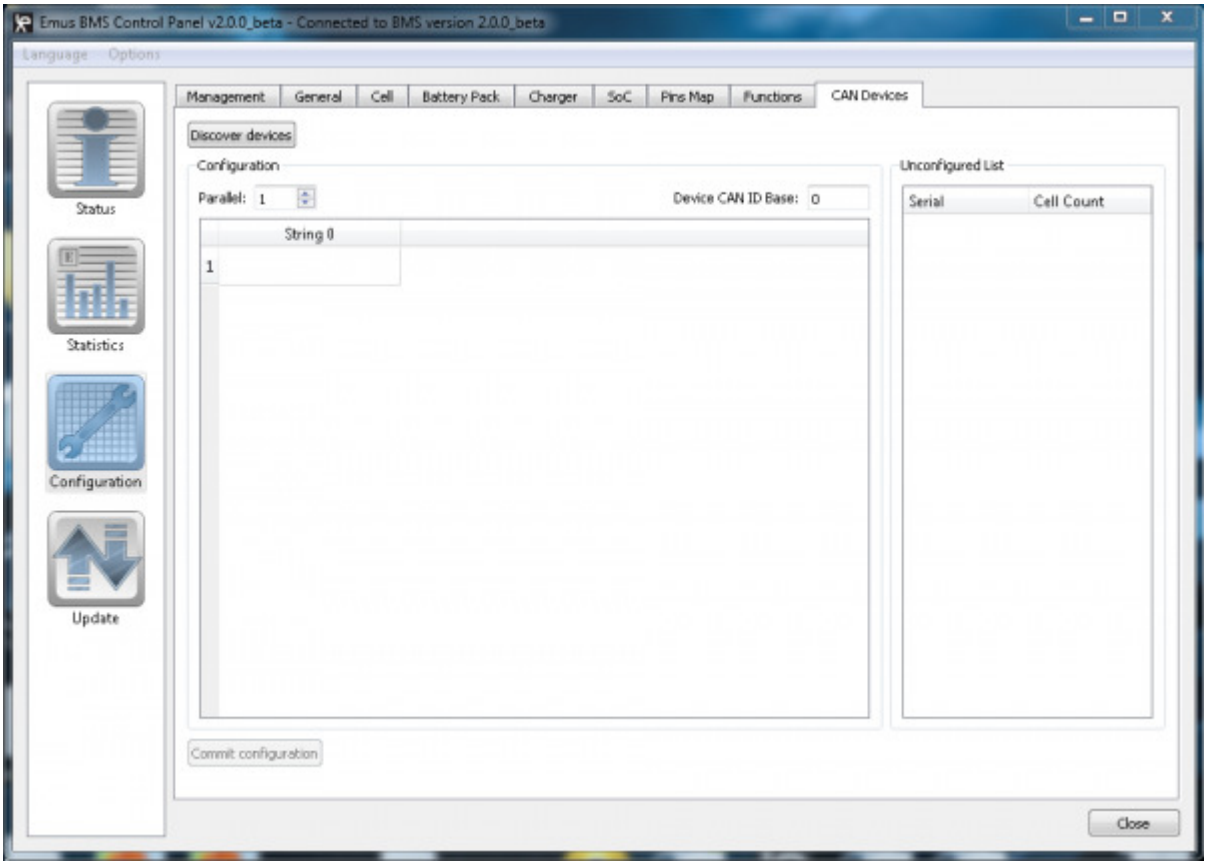
PF15 Leakage Sensor Input

This function is designated for detecting a battery pack leakage event using a leakage sensor. The leakage sensor is external device that should generate a signal of at least +5V in the event of high voltage battery pack circuit leakage to car's chassis or low voltage subsystem.

PF16 Power Reduction Output

This function is intended to signal a power reduction requirement to motor controller of the vehicle in the event of low voltage, high discharge current and overheat.

CAN Devices configuration



BMS Control Panel CAN devices configuration page

CAN Devices configuration allows to discover and configure Emus CAN cell group modules by JSC Elektromotus. The page consists of configuration section and unconfigured devices list. The parameters in this page and the procedure of configuring Can cell group modules are described in detail below.

Discover devices...

Discovers the CAN cell group modules that are connected to BMS CAN bus. The discovered devices appear in the Unconfigured List, where the serial number and cell count of the CAN Cell Group Module is displayed as show in the image below. **CAUTION!:** discovering CAN devices puts BMS Control Unit into configuration mode until the discovery is complete. While in this mode, normal operation of the Control Unit is stopped, therefore is advised to configure CAN cell group modules before the actual use of of Emus BMS system.

Parallel strings

Number parallel cell strings in the configuration table. Increasing this number will create more columns in the configuration table. Adjust this parameter according to the configuration of the battery pack.

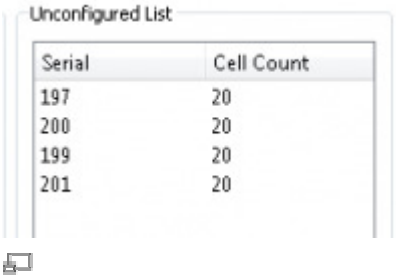
Device CAN ID Base

CAN ID Base address for CAN Cell Group Modules. Each group module's own CAN ID is configured according to this parameter. This allows to resolve the possible addressing conflicts with other devices on the same CAN bus. **NOTE!:** CAN Cell Group Modules use extended 29 bit CAN ID's, and the Base ID represents upper 13 bits of ID. For example the Base ID 0001 is also 0001h in hexadecimal and BMS

broadcast the messages to CAN Cell Group Modules starting from 00010000h and so on.

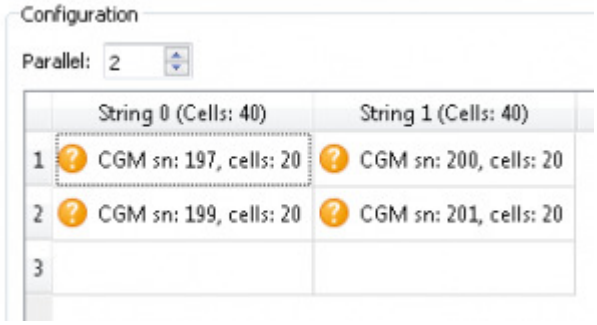
Configuration table

Configuration table consists of columns that represent strings of cells connected in series, and of rows that represent CAN Cell Group Modules in the cell string. For example, if the battery pack consists of two strings connected in parallel, each one of them having 40 cells connected to two CAN cell group modules, then configuration table will have two columns and two rows. After the device discovery, to assign a particular CAN cell group module to a cell

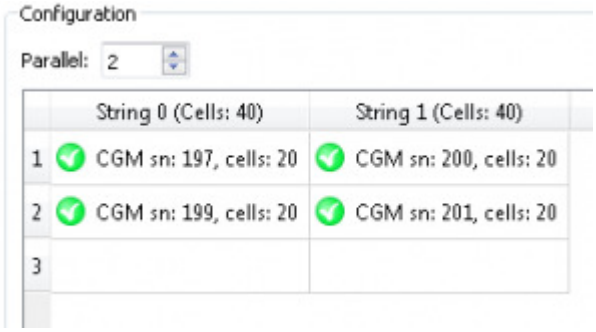


BMS Control Panel CAN devices configuration page: Unconfigured List with some discovered CAN Cell Group Modules

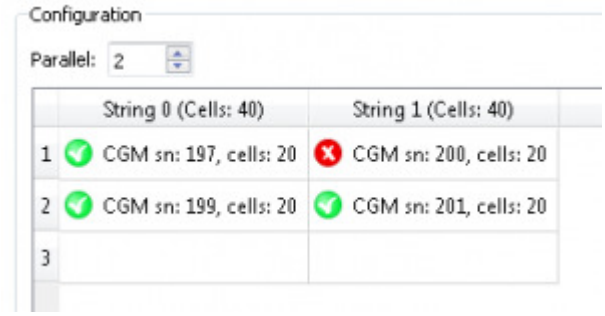
string, simply drag the entry from the unconfigured list to the configured table, and drop on the desired column. This entry will then appear in the configured table with a yellow "question mark" icon. The column headers will be updated, and will display the total cell count of the string, in parentheses next to the string number. This total cell count corresponds to the number of cells of in the string.



BMS Control Panel CAN devices configuration page: Configuration table with four CAN cell group module entries, two in String 0, and two more in String 1. The yellow "question mark" icon indicates that this configuration has not been committed yet.



BMS Control Panel CAN devices configuration page: Configuration table with four CAN cell Group Module entries, after the configuration has been successfully committed and sent to BMS Control Unit. The green "check" icons indicate no errors.



BMS Control Panel CAN devices configuration page: Configuration table with four CAN cell Group Module entries, after committing configuration has failed, and one of the group modules is not responding. The red "x" icon indicates a communication error. In such case, check that the indicated CAN cell group module is connected to the CAN bus correctly.
NOTE!: For purpose of clarity, it is advised to set up the configuration in such way that serial numbers of the CAN cell group modules would be sorted in a downwards ascending order in every column, and also from column to column (see images on the right). This way cells will displayed correctly in Status page, Cells tab: cell of the most negative potential (the one connected to the minus terminal) in the string will be displayed as the first cell on the left, and cell with of the most positive potential (the one connected to the plus terminal) will be the first one on the right. For more detail on how to connect CAN cell group modules, see Installation instructions.
Commit configuration...

After all entries from unconfigured list have been put in the configured table, make sure that every CAN cell group module reports correct cell count. **NOTE!:** If some CAN cell group modules report incorrect cell count please check that the cell modules are installed and connected correctly, and that the cell voltages are high enough to power up the cell modules. If cell count is reported correctly from all CAN cell group module entries, press "Commit configuration" button. Doing so will send the finished configuration to Control Unit and if everything is ok, the yellow question mark icons will turn to green "check" icons, indicating that CAN cell group module configuration was completed successfully. If some error occurred while committing the configuration, some of the yellow question mark icons will turn to red "x" icon indicating an error. In such case, check that CAN cell group modules are connected correctly to the CAN bus.

NOTE!: When CAN group module configuration is committed successfully, Number of Overall Cells, and Number of Cells Strings parameters in Battery Pack configuration tab will be updated automatically.

Configuration by Tasks/Functions

Cell temperature calibration

EMUS BMS measures temperatures of each cell – each of EMUS BMS Cell Modules have temperature probes. These probes require initial calibration to work properly. When all battery cells and EMUS BMS Cell Modules are installed, user must initiate a temperature calibration command. To do so, connect the EMUS BMS Control Unit to PC's USB port, start the EMUS BMS Control Panel application and navigate to *Configuration* page, Battery Pack tab. There you will find a *Calibrate Temperature* button. After pressing the button, type in a current temperature of the battery pack in the prompted window. Ordinary household thermometer is sufficient for getting this reference temperature. Use this calibration only

when all cells are at the same temperature. This will set the temperature of all cells to the one specified. The result can be checked at *Status page*, *Cells tab*, *Temperatures* graph.

NOTE!: Cell temperature probe is situated on Cell Module itself and does not represent an accurate temperature of the cell. Cell tabs do have a good inner thermal conductivity and, usually, Cell Module will report a bit lower temperature, especially at high values. Also keep in mind that Cell Module heats up during balancing stage and reported temperature will be higher than actual.

Configuring the charger

To configure charger used with the Emus BMS, connect the Emus BMS Control Unit to PC's USB port, start the EMUS BMS Control Panel application and navigate to *Configuration* page, *Charger* tab.

Charger Type *dropbox selects a type of charger: with or without CAN interface. Please note that following current settings are applicable for CAN charger only, and can be located in* Configuration *page,* Cells *tab.*

Pre-charge Current field sets a current for pre-charge mode. This mode is active when voltage at any of the cells is lower than the value specified in Pre-charge *Threshold* field. This field is applicable only for CAN charger. **NOTE!**: this parameter is located in *Configuration* page, *Cells* tab.

Pre-charge Threshold field specifies lowest operating voltage of the cells. Typically this value is 3.0 V for LiPO/Li-Ion cells and 2.5 V for LiFePO4. The exact value should be specified in cell manufacturer's datasheet. This field is applicable only for CAN charger.

Slow Charging Current sets a charging rate for charging the vehicle prom lower power, often public outlets. If, for example, the outlet is limited to 1 kW and your cell voltage is 100 V, then *Slow Charge Current* should be set to 10 A (1 kW/ 100 V = 10 A). This field is applicable only for CAN charger.

Fast Charging Current value should be set according to combined ability of the cells, charger and power outlet, whitch one is the lowest. If, for example, the charger can give a 50 A current, but battery cells are 100 Ah and rated at only 0.3 C charge rate, this is a limiting factor and *Normal Charge Current* value should be set to 30 A (100 Ah * 0.3 C = 30 A). This field is applicable only for CAN charger.

Early Balancing Threshold value sets a minimum cell voltage at which cell balancing starts. By lowering this value faster balancing and overall charge time can be achieved, but this increases power losses, dissipated as heat in Cell Modules. Usually threshold of 3.4 V is optimal for LiFePO4 cells and 3.7 V for LiPO/Li-Ion cells.

Allowed Dis-balance value sets the minimum difference between cell voltages at which it is considered that cells are at balance and cell balancing is turned off.

12) Android device

Android devices can download the an application via Google Store "EVGUI".

This application allows a connection to the BMS unit via Blue Tooth (BT Module required) to monitor all data from you battery.